URS # Memorandum

Date:	June 10, 2002
To:	**Julie Mitchell, URS**
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Subject:	**Calculation of Radon Fluxes, Downwind Concentrations, and Radon Risks**

TECHNICAL APPROACH

This initial step required for estimating cancer risks from downwind exposure to radon gas is to estimate the release flux from the various sources of concern. For the Salton Sea Unit 6 Project (SSU6 Project), these sources and their respective release rates were all quantified by the Applicant with the exception of the radon flux from the truck transport of the Geothermal Filter Cake. Following is a description of the methodology used to estimate the emission rate of radon from the filter cake storage, and to evaluate potential incremental cancer risks associated with radon emissions from the entire SSU6 Project, along with an example calculation for one receptor.

Estimation of the radon released from the Geothermal Filter Cake is based upon NRC Guidance for estimation of gaseous flux from a bare source.[1] Parametric values and their sources are also included.

$$\frac{J_D}{R} = \rho E \sqrt{\lambda D_W} \tanh\left(\sqrt{\frac{\lambda}{D_W}} t_D\right) \qquad (1)$$

where:

- J_D = Diffusive gaseous flux (pCi/m^2s)
- R = Radium-226 content of source (pCi/kg)
- ρ = Source bulk density (kg/m^3) = 1,305.2 kg/m^3 [2]
- λ = Radon-222 decay constant (s^{-1}) = $2.088\text{x}10^{-6}\ s^{-1}$ [3]
- E = Radon-222 emanation fraction (unitless) = 0.0798 [4]
- D_W = Gaseous diffusion coefficient (m^2/s) = $1.998\text{x}10^{-6}\ m^2/s$ [4]
- t_D = Average thickness of source (m) = 1.22 m

From the above equation, an average radon flux from the temporary storage of filter cake is calculated to be 1.8 $\text{x}10^{-4}$ pCi/m^2s per pCi/kg radium-226 in the cake. Using the source

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[1] Rogers, V.C., Nielson, K.K., "Radon Attenuation Handbook for Uranium Mill Tailings Cover Design." (NUREG/CR-3533), prepared for the U.S. Nuclear Regulatory Commission, Washington, D.C., 1984.
[2] Carlsen, Bruce, personal communication, May 2001.
[3] Kocher, David C., "Radioactive Decay Data Tables – A Handbook of Decay Data for Application to Radiation Dosimetry and Radiological Assessments." U.S. Department of Energy, 1985.
[4] URS Radiological Laboratory Analysis, performed May 29, 2001.

parameters reported in Table G-10 of Appendix G, this flux is calculated into an annual release rate:

$$\text{Release Rate}\left({}^{pCi}\!/_{s} \; per \; {}^{pCi}\!/_{kg} \right) = \left(1.8\times10^{-4} \frac{pCi}{m^2 s} \; per \; \frac{pCi}{kg} \right)\left(837m^2 \, truck \; surface \; area \right) = 0.151 \qquad (2)$$

From this relative release rate, an absolute release rate is estimated assuming an average radium-226 concentration in the cake of 10 pCi/g (10^4 pCi/kg).

$$\text{Absolute Release Rate}\left(\frac{pCi}{s} \right) = \left(0.151 \frac{pCi}{s} \; per \frac{pCi}{kg} \right)\left(10^4 \frac{pCi}{kg} \right) = 1.51\times10^3 \qquad (3)$$

Table G-10, in Appendix G, indicates that trailers are stored for 8 hours per day, up to 5 days per week. Using this information, the pCi of radon gas relesaed over a year is estimated as follows:

$$\text{Annual Release Rate}\left(\frac{pCi}{yr} \right) = \left(1.51x10^3 \frac{pCi}{s} \right)\left(\frac{60s}{\min} \right)\left(\frac{60\min}{hr} \right)\left(\frac{8hr}{day} \right)\left(\frac{5days}{week} \right)\left(\frac{52weeks}{yr} \right) = 1.13x10^{10} \qquad (4)$$

The radon release rates for the filtercake storage given above and the cooling tower (126 Ci/yr) can then be used to estimate a downwind radon concentration. In order to do this, the atmospheric dispersion and dilution must be quantified. According to NRC, there are numerous means of estimating the effects of the various atmopheric drivers and dilutions. In conjunction with this, there are also numerous models that estimate to various degrees of confidence these characteristics.[5] Furthermore, independent of the model selected, these characteristics can generally be summarized by the long-term dispersion factor (X/Q). The X/Q term represents the ratio of the predicted downwind atmospheric concentration of the constituent of concern (pCi/m^3) to the release rate (pCi/s), and has a precision and uncertainty commensurate with those of the model selected for its estimation.[6]

The effects of atmospheric transport and dispersion processes on the atmospheric concentrations (X/Q) of hazardous pollutants, including radon, were quantified in the health risk assessment for the SSU6 Project (AFC Section 5.15) using the ISCST3 model. The concentrations predicted by ISCST3 were then used as input to the ACE2588 model to predict the associated health risks. The following shows an example calculation of the cancer risk at the maximally exposed individual (MEI), the sensitive receptor located 2.1

[5] Till, John E. and H.R. Meyer, "Radiological Assessment". U.S. Nuclear Regulatory Commission text (NUREG/CR-3332), Washington D.C., 1983.

[6] Slade, David H. "Meteorology and Atomic Energy" U.S. Atomic Energy Commission Report, 1968.

miles east of the SSU6 Project. Using ISCST3 with a representative 5-year meteorological data set resulted in a predicted maximum annual radon concentration at the MEI from the cooling tower, of 0.1348×10^{-6} pCi/m³ per pCi/s of emissions. Therefore, an effective X/Q value for the cooling tower radon emissions is calculated to be (0.1348×10^{-6} pCi/m³)/(1pCi/s)= 1.348×10^{-7} s/m³. Similarly, the maximum X/Q predicted for the filter cake at the MEI was found to be 1.014×10^{-6} s/m³.

These calculated dispersion parameters (X/Q) can then be applied to the radon release rates for the two SSU6 source activities to estimate downwind radon-222 concentrations,

$$Downwind\ Concentration\left(\frac{pCi}{m^3}\right) = Source\left(\frac{pCi}{s}\right)\frac{X}{Q}\left(\frac{s}{m^3}\right) \tag{5}$$

Maximum annual downwind concentrations resulting from the two source activities are then estimated as:

<u>Cooling Tower</u> = 3.997×10^{-6} (Ci/s) x 1.348×10^{-7} (s/m³) = 5.39×10^{-13} Ci/m³= 5.39×10^{-1} pCi/m³

<u>Filter Cake Storage</u> = 1.51×10^{-9} (Ci/s) x 1.014×10^{-6} (s/m³) = 1.53×10^{-15} Ci/m³ = 1.53×10^{-3} pCi/m³

However, in the case of the filter cake storage source, the above predicted concentration actually represents the concentration during times that the trucks are being stored (5 days per week and 8 hours per day). The effects of the remaining 16 hours of the day when no source is present must be accounted for when estimating an annual average concentration (required before applying the HEAST cancer slope factor described below). Therefore, this concentration must be multiplied by the fraction of the year when the source is present.

$$\begin{array}{l} Annual\ Average \\ Concentration \\ Downind\ of\ Trucks \end{array} = \left(3.67x10^{-3}\ {}^{pCi}\!/\!_{m^3}\right)\frac{\left(\frac{8hr}{day}\right)\left(\frac{5day}{week}\right)}{\left(\frac{24hr}{day}\right)\left(\frac{7day}{week}\right)} = 3.65x10^{-4}\ {}^{pCi}\!/\!_{m^3} \tag{6}$$

From these downwind concentrations, cancer mortality can be calculated. The U.S. EPA estimates cancer mortality from radon exposure based solely on atmospheric concentration (as opposed to quantity ingested). Accordingly, EPA estimates 2.2×10^{-4}

fatal cancers per Working Level Month (WLM).[7] One WLM is equal to 170 hours of exposure at a concentration of 1 Working Level (WL), and one WL is equivalent to a concentration of 100 pCi/L at 100% daughter equilibrium (or a concentration of 200 pCi/L at 50% daughter equilibrium),[8] For this analysis the standard U.S. EPA 10% radon equilibrium was used. The basic risk factor of 2.2×10^{-4} risk/WLM is then multiplied by the following factors:

$$RCF_{1,Rn}\left(\frac{fatal\ cancers}{pCi/m^3}\ per\ year\ exposure\right) = (0.10 equilibrium)\left(2.2x10^{-4}\frac{fatal\ cancers}{WLM}\right)\frac{\left(8{,}760\frac{hr}{yr}[WLM]\right)}{\left(170\frac{working\ hr}{month}[WL]\right)}\left(\frac{1WL}{100\,pCi/L}\right)\left(\frac{1m^3}{1{,}000L}\right) \tag{7}$$

The result is 1.13×10^{-8} fatal cancers per year of exposure per pCi/m³. This risk factor is the fatal cancer risk for an individual exposed outdoors for 100% of the time (24 hours per day, 365 days per year) for one year. For a 70-year exposure, the risk should be multiplied accordingly, $1.13\text{x}10^{-8} \times 70 = 7.94 \times 10^{-7}$ fatal cancers per pCi/m^{3}[9].

Therefore, resulting cancers from downwind concentrations are calculated as:

Cooling Tower = ($5.39\text{x}10^{-1}$ pCi/m^3)($7.94\text{x}10^{-7}$ cancers per pCi/m^3) = 0.428 cancers per million

Temporary Storage = ($3.65\text{x}10^{-4}$ pCi/m^3)($7.94\text{x}10^{-7}$ cancers per pCi/m^3) = $2.89\text{x}10^{-4}$ cancers per
million

[7] U.S. Environmental Protection Agency, "Health Risks From Low-Level Environmental Exposure To Radionuclides – Federal Guidance Report No. 13" (EPA 402-R-97-014), U.S. Environmental Protection Agency, Washington D.C., 1998.
[8] Cember, Herman. "Introduction to Health Physics". McGraw-Hill. New York, 1983.
[9] U.S. Environmental Protection Agency, "Exposure Factors Handbook" (EPA/600/P-95/002Bc) U.S. Environmental Protection Agency, Washington D.C., 1996.